

Knowledge and Practices of Circular Agriculture among Corn Farmers for Climate Change Mitigation: Evidence from Indonesia

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Abstract. *Implementing sustainable agricultural practices is a crucial approach that corn farmers in Gorontalo should adopt towards mitigating climate change. This study aims to determine the level of knowledge and practices of circular agriculture among corn farmers and to identify socio-economic characteristics that correlate with their knowledge and practices of circular agriculture. A total of 300 corn farmers from eight villages in Suwawa Selatan, Indonesia, were interviewed through a questionnaire that included statements related to their knowledge and practices of circular agriculture. The results of the statistical analysis of the data showed that farmers exhibited a lack of knowledge regarding various aspects of circular agriculture, including the use of organic fertilizer, intercropping, minimum tillage, and crop rotation. On the other hand, farmers were found to rarely practice crop rotation, intercropping, and use of organic fertilizer, despite these being crucial components of circular agriculture. Furthermore, the study identified several characteristics that were found to be correlated with farmers' knowledge and practices of circular agriculture, including education level, farm size, and participation in agricultural extension programs. Based on these findings, it is essential to strengthen agricultural extension programs to increase farmers' knowledge and practices of circular agriculture to mitigate climate change.*

Keywords: agricultural extension, circular agriculture, Indonesia

JEL Codes: Q16

1. Introduction

Indonesia, a nation whose economy largely depends on agriculture, employs a substantial portion of its workforce in the agricultural sector. The Central Bureau of Statistics or BPS has reported that approximately 88.89% of Indonesians work in agriculture (Badan Pusat Statistik, 2022). However, despite the prevalence of agriculture in the country, many farmers are unfamiliar with appropriate methods for sustainable agriculture. This knowledge gap has led to negative consequences on a global scale, as agricultural activities contribute significantly to global warming and ultimately climate change. These agricultural practices may exacerbate the effects of climate change by increasing global warming.

Consequently, climate change has a significant impact on farmers, with crop failure and extreme weather being among the most notable negative effects. Moreover, extreme climate change has the potential to damage land resources in the agricultural sector, increase the frequency and severity of droughts, and worsen pest infestations. Agricultural activities are recognized as a primary contributor to climate change, with the burning of agricultural waste being one of the significant causes. In Indonesia, an estimated 45 million tons of agricultural waste are burned annually (Andini et al., 2018), producing not only greenhouse gas emissions that contribute to global warming and climate change but also hazardous substances that adversely affect human health and local environmental conditions. Additionally, cow manure may also contribute to climate

change, particularly dairy cow faeces that generate methane gas, known as CH₄. Poor management practices that result in the release of livestock waste may contribute to methane pollution.

The issue of unsustainability in the agricultural system and its consequential effects on global warming and climate change in Indonesia should be addressed through the adoption of effective circular agricultural management practices. Mitigating climate change can be achieved through the implementation of circular agriculture, a sustainable food production approach that prioritizes maintaining agro-ecosystem health, minimizing biomass and nutrient losses, and efficiently reusing and recycling agricultural residues while reducing energy consumption (Silvius et al., 2023). This model replaces the traditional linear system of "take-produce-consume-discard" with a zero-waste paradigm, emphasizing the reuse and recycling of by-products (Hoogstra et al., 2024). It promotes efficient utilization of nutrients and biomass to enhance food production through strategies such as mixed farming that diversifies crop and livestock commodities, organic farming that leverages agricultural waste, and agroforestry practices (Helgason et al., 2021). As mitigation of the adverse impacts of climate change, concerted efforts need to be made to ensure that farmers have access to meaningful information and education on vital aspects of circular agriculture. Therefore, there is an urgent need to disseminate knowledge and practices of circular agriculture on corn farming techniques. According to Abanigbe et al. (2024), farmers who are unknowledgeable of the potential benefits of climate change adaptation strategies may be less likely to invest in new infrastructure or technologies.

Bone Bolango, located in the Province of Gorontalo, Indonesia, is primarily a rural district where the economy relies heavily on the agricultural sector. This sector accounts for as much as 22.47% of the workforce. Suwawa Selatan District, a district or kecamatan in Bone Bolango Regency covering an area of 242.57 km², is primarily an agriculture-based district with corn farming being a crucial agricultural sector. Research conducted by Dunggio et al. (Dunggio et al., 2022) has identified the pattern of corn farming as one of the causes of environmental degradation in Bone Bolango Regency, which also occurred in other regencies such as Gorontalo Regency (Mamangkay et al., 2023). This underscores the significance of enhancing awareness, erudition, and transformative shifts in agricultural practices among farmers in pursuit of more judicious and ecologically sustainable approaches to corn farming methods. Certain studies expound upon exemplary manifestations of such circular agriculture practices, including the utilization of organic fertilizers (Lokonon & Mbaye, 2018), limiting the excessive application of chemical pesticides that pose a threat to biodiversity (Rajmohan et al., 2020), reducing excessive tillage characterized by vigorous plowing to avert erosion and soil degradation (Huang et al., 2018), implementing crop rotation to protect essential soil nutrients and mitigate erosion (Lokonon & Mbaye, 2018), adopting intercropping techniques to optimize production outcomes while concurrently preserving soil fertility (Ng'ombe et al., 2020), engaging in the processing of agricultural waste to mitigate environmental harm and its consequential impact on greenhouse gas emissions (Tongwane et al., 2016), and embarking upon reforestation endeavors to fortify topsoil integrity by planting trees as a protection against erosion (Lokonon & Mbaye, 2018).

The adoption of circular agricultural practices can be facilitated through agricultural extension programs, encompassing the dissemination of information and the provision of non-formal educational resources to farmers, elucidating the significance of prudent and eco-friendly agricultural management. To ensure the optimal implementation of agricultural extension initiatives, a comprehensive understanding of farmers' knowledge concerning the importance of circular agriculture, as well as the degree to which circular agricultural practices have been implemented, becomes imperative. It is expected that agricultural extension possesses the ability to design, coordinate, and conduct counselling activities tailored to meet the specific requirements of farmer groups as the target community. Consequently, there arises a necessity to delineate the service requirements of agricultural extension endeavors within the purview of circular agriculture, with a particular focus on knowledge acquisition and its practical application by farmers. Hence, the primary

objective of this research is to identify the specific extension needs pertinent to circular agriculture, serving as a mitigation for climate change. The specific objectives of this study encompass the identification of farmers' knowledge levels and adoption rates concerning circular agricultural practices, and the identification of farmer characteristics correlated with their knowledge and practices of circular agriculture.

2. Research Elaboration

2.1. Research methods

The study was undertaken in Suwawa Selatan, Indonesia. The selection of this geographical area was based on an assessment of prevailing challenges within the location, where the majority of the local population is engaged in corn farming. The deleterious ecological consequences arising from unsustainable practices employed in corn cultivation have been identified as a significant contributing factor to environmental degradation within the broader confines of the Bone Bolango Regency (Dunggio et al., 2022; Salote et al., 2022). Given the district's vulnerability to recurrent environmental disasters, it becomes imperative to investigate this specific area.

2.2. Data collection and analysis

The data collection process in this study encompassed 300 corn farmers residing in Suwawa Selatan. A purposively designed questionnaire served as the primary instrument for data collection, aiming to capture pertinent information related to the socio-economic attributes of the respondents, as well as their level of knowledge and practices regarding circular agriculture within the domain of corn farming. The observed variables in this investigation included aspects such as the use of organic fertilizers, crop rotation, and planting tree initiatives (Lokonon & Mbaye, 2018), the minimum or reduced tillage to prevent erosion (Huang et al., 2018), intercropping (Ng'ombe et al., 2020), and agricultural waste management practices (Tongwane et al., 2016).

The assessment of the degree of knowledge regarding circular agriculture variables was conducted by employing a five-level Likert scale that encompassed a range of response options: "very well understood," "moderately understood," "neutral," "lacked understanding," and "did not understand". For inquiries pertaining to the degree of practice of circular agriculture, the response options included "always," "quite often," "sometimes," "rarely," and "never." Descriptive analysis was employed to examine the extent of knowledge and practices of circular agriculture among corn farmers. Furthermore, statistical tests with Spearman-rank correlation were conducted to explore the associations between socio-economic characteristics and the levels of knowledge and practices of circular agriculture.

3. Results and Discussion

3.1. Research site

The study was carried out in Suwawa Selatan, encompassing eight villages. Suwawa Selatan spans an area of 242.57 km², as illustrated in Figure 1. In terms of geographic positioning, Suwawa Selatan is bordered by Suwawa Tengah to the north, Suwawa Timur to the east, Bonepantai to the south, and Botupingge to the west.



Fig. 1: Research site (source: authors' contribution)

3.2. Respondent characteristics

The participants in this study comprised a total of 300 corn farmers who reside in Suwawa Selatan. This region is known for its agricultural activities, particularly corn farming. These farmers were selected to provide a representative sample of the local farming community, ensuring that the study captures diverse perspectives and farming practices. The selection process took into account various factors such as age, gender, education level, farm size, and years of experience in farming, allowing for a more comprehensive analysis of their socio-economic conditions. In addition to that, Involvement in farmers' groups and extension activities was also considered. A detailed breakdown of the demographic and socio-economic attributes of the participants is presented in Table 1.

Table 1: Socio-economic characteristics of respondents

Characteristics	Percentage
Age	
< 20 years	0.0% (0)
20-29	5.0% (15)
30-39	13.3% (40)
40-49	32.0% (96)
50-59	30.7% (92)
Above 60	19.0% (57)
<i>Average: 48.93 years</i>	
Gender	
Male	71.3% (214)
Female	28.7% (86)
Education level	
Uneducated	28.7% (86)
Primary school	48.7% (146)
Middle school	14.0% (42)
High school	6.7% (20)
College and above	2.0% (6)
Farm size (in Hectare)	
Less than 1	15.7% (47)
1 - 2	79.7% (239)
Above 2	4.7% (14)
<i>Average: 1.27 Ha</i>	
Farming experience (in Years)	
Less than 5 years	11.0% (33)
5 - 10 years	22.3% (67)
11-20 years	27.0% (81)
Above 20 years	39.7% (119)
<i>Average: 19.76 years</i>	

(Source: Primary data)

Table 1 provides insights into the demographic characteristics of farmers in Suwawa Selatan. It reveals that the majority of farmers in these areas fall within the age range of approximately 40 years and older, indicating a lack of young farmers. This aligns with the findings of previous studies conducted by Arsyad and Sirajuddin (2023) on corn farmers in Gorontalo, which similarly highlighted that a significant proportion of corn farmers in Gorontalo Province belong to the age group of the 40s. Furthermore, the data indicate that the respondents in the research location generally possess a low level of education. This finding is consistent with recent studies that have reported the prevalence of low education levels among farmers in Gorontalo (Suhana et al., 2023). Prasetya has suggested that the educational background of rural communities significantly influences their employment structure, with individuals possessing higher education tending to seek non-agricultural employment opportunities (Prasetya & Putro, 2019).

Table 2: Farmers' involvement in farmer groups and extension activities

Items	Percentages
<i>Involvement in a farmers' group</i>	
Always	49.3% (148)
Often	17.3% (52)
Sometimes	4.7% (14)
Rarely	4.0% (12)
Never	24.7% (74)
<i>Involvement in extension activities</i>	
Always	46.7% (140)
Often	19.7% (59)
Sometimes	7.7% (23)
Rarely	7.3% (22)
Never	18.7% (56)

(Source: Primary data)

Table 2 indicates that a significant proportion of farmers actively participate in both farmer group activities and agricultural extension programs. The data reveal that these farmers demonstrate considerable engagement, contributing to the overall success and functionality of both initiatives. Notably, nearly half of the respondents report a high level of involvement in these activities, highlighting their dedication to collaborative efforts within farmer groups and their commitment to learning and adopting new agricultural practices through extension services. This active participation underscores the important role of farmer groups and agricultural extension in enhancing knowledge on circular agriculture, fostering community cooperation, and improving farming outcomes.

3.3. Knowledge and practices of circular agriculture among corn farmers

An assessment of knowledge and practices regarding circular agriculture was conducted using a questionnaire that employed a Likert scale measurement. The scale consisted of five levels, including "very well understood," "moderately understood," "neutral," "lacked understanding," and "did not understand", for knowledge aspects, and "always," "quite often," "sometimes," "rarely," and "never" for practices aspects (both were rated from 1 to 5). The numerical conversion was subsequently determined by calculating the median for each item and the mean for overall aspects. Table 3 presents the values pertaining to knowledge and practices concerning circular agriculture in Suwawa Selatan.

Table 3 illustrates the farmers' level of knowledge regarding farming behaviour associated with circular agriculture. The findings reveal that farmers possess limited comprehension in several areas. Specifically, they exhibit a solid understanding of the significance of tree planting in preventing soil erosion. However, their knowledge regarding other aspects, which included the importance of implementing crop rotation, minimizing excessive ploughing that can lead to erosion, and adopting intercropping and crop rotation, remains low. In terms of practical implementation, farmers demonstrate moderate adherence to minimum tillage and planting trees. Conversely, they exhibit no practices of other recommended circular agricultural practices, including the application of organic fertilizers, using intercrop and crop rotation within their farming activities.

Table 3: Knowledge and practices of circular agriculture

Items	mean	median
Knowledge		
Planting trees		4 (<i>moderately understood</i>)
Use of organic fertilizer		1 (<i>did not understand</i>)
Intercrop		1 (<i>did not understand</i>)
Minimum tillage		1 (<i>did not understand</i>)
Crop rotation		1 (<i>did not understand</i>)
<i>Overall average</i>	2.51	
Practices		
Minimum tillage		3 (<i>sometimes</i>)
Planting trees		3 (<i>sometimes</i>)
Crop rotation		1 (<i>never</i>)
Intercrop		1 (<i>never</i>)
Use of organic fertilizer		1 (<i>never</i>)
<i>Overall average</i>	2.04	

(Source: Primary data)

The mean values of overall knowledge ($\bar{x}=2.51$) and practices ($\bar{x}=2.04$) indicate that farmers' understanding and implementation of circular agricultural methods, which have a positive environmental impact, are currently at a low level. This poses a significant challenge, particularly for agricultural extension services in the research area, as it requires concerted and comprehensive efforts to enhance awareness and knowledge regarding circular agriculture in corn farming. By doing so, farmers can effectively reduce negative environmental consequences and actively contribute to climate change mitigation. Agricultural extension services play a pivotal role in this regard, serving as a non-formal educational platform for farmers to collectively acquire knowledge and address climate change-related issues.

3.4. Socio-economic demographic characteristics correlated with farmers' knowledge and practices of circular agriculture

A statistical analysis was conducted to examine the potential associations between various demographic and socio-economic characteristics of farmers and their knowledge and practices pertaining to circular agriculture in Suwawa Selatan. Identifying correlated characteristics can assist policymakers in formulating targeted strategies to assist farmers in addressing climate change challenges effectively. To assess correlations, the Pearson and Spearman's rank correlation test was employed, considering that some variables measuring knowledge and practices in this study were naturally ordinal variables. The outcomes of the statistical analysis are presented in Table 4.

Table 4: Variables correlated with knowledge and practices of circular agriculture

Item	Coefficient	Significance
Knowledge		
Age	-.039	-
Farm size	-.019	-
Farming experience	.041	-
Education level	.153	sig**
Involvement in farmer's group	.042	-
Involvement in extension activities	.175	sig**
Practices		
Age	-.043	-
Farm size	.171	sig**
Farming experience	.029	-
Education level	.037	-
Involvement in farmer's group	.083	-
Involvement in extension activities	.170	sig**

Note: **= correlation found at .01, *= correlation found at .05

Source: authors' computation

The statistical analysis reveals significant correlations between certain characteristics of farmers and their knowledge and practices regarding circular agriculture. Table 4 illustrates that education level exhibits correlations with knowledge pertaining to the importance of circular agriculture. This study demonstrated that education is a key factor in enhancing farmers' understanding, particularly in acquiring new strategies and adopting innovative agricultural practices. The findings align closely with research conducted by Tarakini et al. (2020), which similarly highlighted the positive correlation between education and farming expertise. Farmers with higher levels of education tend to possess a more comprehensive knowledge of farming practices, enabling them to make informed decisions, embrace advanced techniques, and adapt more effectively to changes in the agricultural landscape. This underscores the critical role education plays in empowering farmers and improving the overall efficiency and sustainability of agricultural operations. Meanwhile, Table 4 also shows that farm size is highly correlated with circular agriculture practices among corn farmers. Serebrennikov et al. (2020) explained that the size of a farm serves as an indirect indicator of farmers' financial capacity, suggesting that larger farm sizes are typically better positioned to allocate resources toward the adoption of sustainable technologies. Financial strength associated with bigger farms provides them with greater flexibility and access to the capital required for investing in advanced, eco-friendly practices. This economic advantage enables larger farms to implement sustainable solutions more effectively, contributing to long-term agricultural resilience and environmental stewardship.

Notably, active involvement in agricultural extension significantly correlated with farmers' knowledge and practices concerning circular agriculture. This underscores the crucial role of agricultural extension services in Suwawa Selatan in enhancing farmers' knowledge and practices regarding circular agriculture and its positive impact on climate change mitigation. Aligning with this study, Tripathi and Mishra also emphasized the significance of effective agricultural extension in improving farmers' knowledge of climate

change (Tripathi & Mishra, 2017). Moreover, Ozioko et al. (2022) highlighted the significant importance of enhancing the skills and knowledge of agricultural extension agents to better equip them for addressing the challenges posed by climate change. Extension agents play a vital role in supporting farmers, particularly in adapting to the shifts in climate that directly impact agricultural productivity. Strong capacities of extension agents will enable them to provide farmers with effective strategies, tools, and guidance needed to mitigate the adverse effects of climate change and sustain their livelihoods.

4. Conclusions

Knowledge and practices of circular agriculture among corn farmers in the context of climate change mitigation remain notably low, indicating the need for increased efforts to enhance farmers' knowledge and practices of circular agricultural implementation that can positively contribute to the environment. Agricultural extension services play a crucial role in enhancing farmers' knowledge and practices of circular agriculture, highlighting the importance of strengthening agricultural extension initiatives to promote and disseminate circular agricultural practices within the framework of climate change mitigation.

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Statement of AI Tool Usage: During the preparation of this manuscript, the authors used ChatGPT solely for the purpose of language refinement. This included grammar correction, sentence restructuring, and improving overall readability. All intellectual content, analysis, and conclusions remain my own. No AI tools were used for data generation, interpretation, or the development of core scientific arguments.

6. References

- [1] Abanigbe, S. A., Ngidi, M. S., Ojo, T. O., Oyedeji-Amusa, M. O., Orowole, P., Yusuf-Oshoala, M., & Adebayo, B. (2024). Adoption of climate change adaptation strategies and household food security of smallholder poultry farmers in Lagos and Ogun States, Nigeria. *Journal of Agricultural Extension*, 28(4), 120–130. <https://doi.org/10.4314/jae.v28i4.12>
- [2] Andini, A., Bonnet, S., Rousset, P., & Hasanudin, U. (2018). Impact of open burning of crop residues on air pollution and climate change in Indonesia. *Current Science*, 115(12), 2259–2266. <https://doi.org/10.18520/cs/v115/i12/2259-2266>
- [3] Arsyad, K., & Sirajuddin, Z. (2023). Partisipasi petani jagung dalam kelompok tani untuk mengakses Kredit Usaha Rakyat. *Innofarm: Jurnal Inovasi Pertanian*, 25(1), 1–7.
- [4] Badan Pusat Statistik. (2022). *Persentase Tenaga Kerja Informal Sektor Pertanian (Persen)*, 2020-2022. Badan Pusat Statistik. <https://www.bps.go.id/indicator/6/1171/1/persentase-tenaga-kerja-informal-sektor-pertanian.html>
- [5] Dunggio, I., Lihawa, F., & Hasan, R. (2022). Dinamika perubahan tutupan hutan dan lahan di sub DAS Tamalate Kabupaten Bone Bolango. *Gorontalo Journal of Forestry Research*, 5(2), 91–100. <https://doi.org/https://doi.org/10.32662/gjfr.v5i2.2451>
- [6] Helgason, K., Iversen, K., & Julca, A. (2021). *Circular agriculture for sustainable rural development*. <http://bit.ly/wsr2021>.

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- [7] Hoogstra, A. G., Silvius, J., de Olde, E. M., Candel, J. J. L., Termeer, C. J. A. M., van Ittersum, M. K., & de Boer, I. J. M. (2024). The transformative potential of circular agriculture initiatives in the North of the Netherlands. *Agricultural Systems*, 214. <https://doi.org/10.1016/j.agsy.2023.103833>
 - [8] Huang, Y., Ren, W., Wang, L., Hui, D., Grove, J. H., Yang, X., Tao, B., & Goff, B. (2018). Greenhouse gas emissions and crop yield in no-tillage systems: A meta-analysis. *Agriculture, Ecosystems and Environment*, 268, 144–153. <https://doi.org/10.1016/j.agee.2018.09.002>
 - [9] Lokonon, B. O. K., & Mbaye, A. A. (2018). Climate change and adoption of sustainable land management practices in the Niger basin of Benin. *Natural Resources Forum*, 42(1), 42–53. <https://doi.org/10.1111/1477-8947.12142>
 - [10] Mamangkay, B., K. Baderan, D. W., Susanti Hamidun, M., & Dunggio, I. (2023). Pola aktivitas pengolahan pertanian jagung yang berdampak pada kerusakan lingkungan di Kabupaten Gorontalo. *Jambura Geo Education Journal*, 4(1), 12–24. <https://doi.org/10.34312/jgej.v4i1.17258>
 - [11] Ng'ombe, J. N., Tembo, M. C., & Masasi, B. (2020). “Are they aware, and why?” Bayesian analysis of predictors of smallholder farmers’ awareness of climate change and its risks to agriculture. *Agronomy*, 10(3), 1–22. <https://doi.org/10.3390/agronomy10030376>
 - [12] Ozioko, R. I., Eze, K. C., Emordi, A. N., Okoronkwo, D. J., & Nwobodo, C. E. (2022). Capability of extension agents in disseminating climate change information in Delta State Nigeria. *Journal of Agricultural Extension*, 26(3), 74–85. <https://doi.org/10.4314/jae.v26i3.7>
 - [13] Prasetya, N. R., & Putro, S. (2019). Hubungan tingkat pendidikan dan umur petani dengan penurunan jumlah rumah tangga usaha pertanian sub sektor tanaman pangan di Desa Meteseh Kecamatan Boja Kabupaten Kendal. *Edu Geography*, 7(1), 47–56. <https://doi.org/https://doi.org/10.15294/edugeo.v7i1.30134>
 - [14] Rajmohan, K. S., Chandrasekaran, R., & Varjani, S. (2020). A review on occurrence of pesticides in environment and current technologies for their remediation and management. *Indian Journal of Microbiology*, 60(2), 125–138. <https://doi.org/10.1007/s12088-019-00841-x>
 - [15] Salote, M. K., Lihawa, F., & Dunggio, I. (2022). Hubungan kondisi sosial ekonomi masyarakat petani terhadap degradasi lahan di DAS Alo Pohu Provinsi Gorontalo. *Jambura Geo Education Journal*, 3(3), 88–96. <https://doi.org/10.34312/jgej.v4i1.14838>
 - [16] Serebrennikov, D., Thorne, F., Kallas, Z., & McCarthy, S. N. (2020). Factors influencing adoption of sustainable farming practices in europe: A systemic review of empirical literature. In *Sustainability (Switzerland)* (Vol. 12, Issue 22, pp. 1–23). MDPI. <https://doi.org/10.3390/su12229719>
 - [17] Silvius, J., Hoogstra, A. G., Candel, J. J. L., de Olde, E. M., de Boer, I. J. M., & Termeer, C. J. A. M. (2023). Determining the transformative potential of circular agriculture initiatives. *Ambio*, 52(12), 1968–1980. <https://doi.org/10.1007/s13280-023-01894-5>
 - [18] Suhana, S., Rauf, A., & Sirajuddin, Z. (2023). Adopsi Good Agricultural Practice (GAP) jagung hibrida untuk meningkatkan produktivitas jagung oleh petani. *Ziraa 'ah*, 48(1), 101–114.
 - [19] Tarakini, G., Chemura, A., & Musundire, R. (2020). Farmers’ knowledge and attitudes toward pollination and bees in a maize-producing region of Zimbabwe: Implications for pollinator conservation. *Tropical Conservation Science*, 13. <https://doi.org/10.1177/1940082920918534>
 - [20] Tongwane, M., Mdlambuzi, T., Moeletsi, M., Tsubo, M., Mliswa, V., & Grootboom, L. (2016). Greenhouse gas emissions from different crop production and management practices in South Africa. *Environmental Development*, 19, 23–35. <https://doi.org/10.1016/j.envdev.2016.06.004>
 - [21] Tripathi, A., & Mishra, A. K. (2017). Knowledge and passive adaptation to climate change: An example from Indian farmers. *Climate Risk Management*, 16, 195–207. <https://doi.org/10.1016/j.crm.2016.11.002>

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